

A CONSIDERATION ON BARRIER FACE SPECIFICATIONS OF SIDE IMPACT MDB

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ABSTRACT

In recent years, the specification of a Side Impact Moving Deformable Barrier (MDB) has been in discussion internationally. This paper describes the results of our investigation and examination concerning the MDB specification, based on current Japanese models. The paper describes the following.

- 1) The Investigation of the dimension of passenger cars in the Japanese market to determine the average of car front-end dimension characteristics.
- 2) The Analysis of force distribution on the rigid barrier in a frontal barrier impact test of typical Japanese passenger car models by using FEM.
- 3) Comparison of test results between a car-to-car test using the passenger car with average front-end characteristic as a striking car and a MDB-to-car test under ECE R95 test condition.

As the results of these studies, we summarize the necessary considerations to represent real vehicle for the design of the MDB face for a future internationally harmonized procedure of side impact testing under consideration by the Harmonization Research Activity ("IHRA") of Side Impact Test Procedures.

INTRODUCTION

Recently, in the IHRA Side Impact Working Group ("WG"), future internationally harmonized procedures of side impact tests were discussed. The IHRA Side impact WG suggests the following four test procedures to enhance side impact protection; 1) MDB to Car Test, 2) Car to Pole Test, 3) Out-of-Position side airbag evaluation test(s), 4) Sub-system head impact test. For the MDB to Car Test procedure, considering the increasing number of SUVs in the market, adopting an MDB that is heavier and has a higher barrier face than the current MDB adopted in the side impact test procedure in Japan and Europe was considered. Under IHRA WG activities, Japan has reported that the average longitudinal member bottom height of the

vehicles registered in 1998 was about 376 mm in the investigation of vehicle front-end dimension for Japanese passenger cars, Mini-Vans and SUVs.

IIHS conducted a series of tests where a Grand Marquis was struck by a Ford F150 in order to study side impact compatibility. IIHS conducted the tests on the five models of Ford F150 with different heights and mass, and they reported that the Ford F150 4×4 that had the heaviest mass and the highest height among the five models did not always produce the most severe results. According to the IIHS report, the reason for this is that the deformation of the Grand Marquis caused this uniform pattern of deformation condition because the front bottom structure of the Ford F150 4×4 struck the strongest structural member of the Grand Marquis struck vehicle.

Taking into account the results of the investigation on vehicle front-end dimension in Japan and the results of the study by the IIHS, the Japan Automobile Manufacturers Association Side Impact Working Group, expected that the lateral member should also transfer load to the struck object in addition to the longitudinal members at the impact. We conducted the frontal impact FEM simulations to study the loading condition for the struck object, the comparison of the full-scale side impact test between MDB to Car and Car to Car, and the investigation on lateral member height of Japanese vehicles. Considering these studies, we discussed the MDB barrier face geometry to be used in future procedures of the side impact test.

This report is the summary of the presentation by the JAMA in the 8th IHRA Side Impact WG.

DATA OF DIMENSION INVESTIGATION

The dimension data used in this study were obtained from the 123 kinds of vehicle marketed in 1998 by Japanese manufactures. Type of the selected vehicles are; 72 kinds of Bonnet Types (normal sedan), 27 Mini-Vans, 17 SUVs, and 10 Cab-over Types.

The data cover about 76% of 5,770,000 vehicles newly registered in 1998, and amounts to about 4,630,000 vehicles

FEM ANALYSIS

To understand the loading condition for struck vehicle, front impact FEM analysis was made. In this study, the force distribution on the flat wall under full front impact was evaluated (See Figure 1). Considering the average longitudinal member bottom height is 376 mm, three representative models of a small hatchback vehicle, small sedan and medium sedan were selected. All these models are high production volume and have similar longitudinal member bottom height.

The FEM results of three representative passenger cars are reviewed in the following:

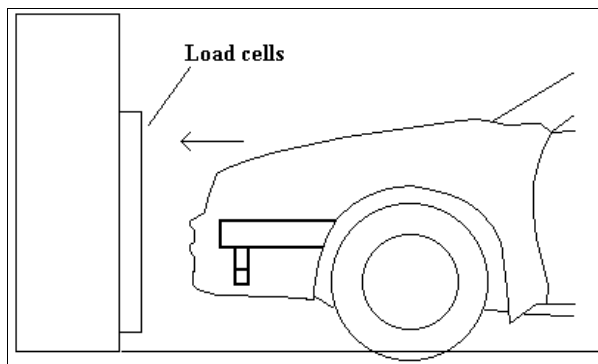


Figure 1. Detail of FEM

Results of FEM Analysis – 1 (the case of medium sedan)

The impacting force generated by the lateral member (front cross member) under the longitudinal member (front side member) is shown in figure 2. The force below 300 mm in height above the ground occurs after 250 mm vehicle deformation (See figure 3). The force level is about 1/5 of the total force.

The longitudinal member bottom height of this model is 415 mm and lateral member bottom height is 210 mm. The other two models discussed in this paper have similar dimension. As seen in Figure 3, in the case of this model, the force below 300 mm height is observed.

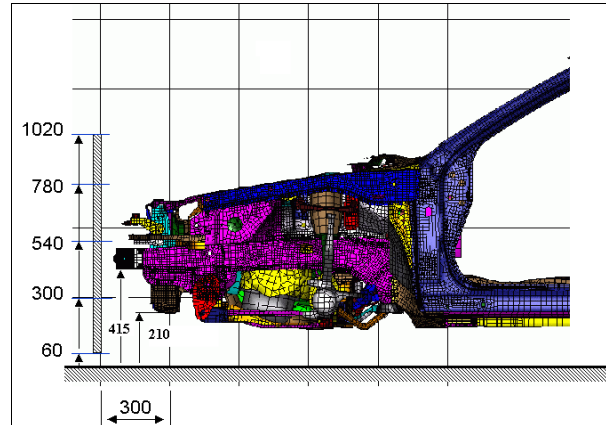


Figure 2. Side view of the medium sedan

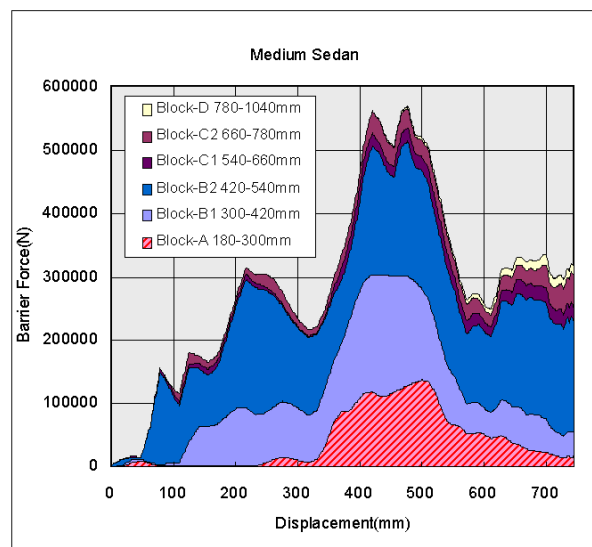


Figure 3. The force distribution of the medium sedan

Results of FEM Analysis – 2 (the case of small hatchback)

Figure 4, 5 show the condition of force distribution on the struck surface.

Figure 4 shows the condition of force distribution at 7-msec after impact when the deformation of the body is 100 mm, and Figure 5 shows that at 14-msec after impact when the deformation is 200 mm. In both 7-msec (Figure 6, 100 mm deformation) and 14-msec (Figure 6, 200 mm deformation), high force level was observed at heights of 280~480 mm, but force was observed at a height of 130~280mm where the lateral member was located.

As seen in Figure 4, 5, in the case of this model, the force below 300 mm height is observed.

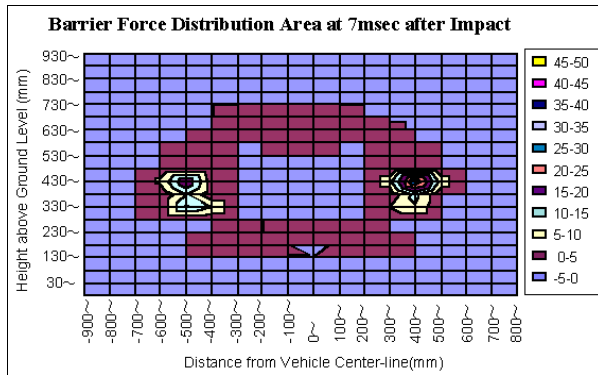


Figure 4. The condition of force distribution at 7-msec

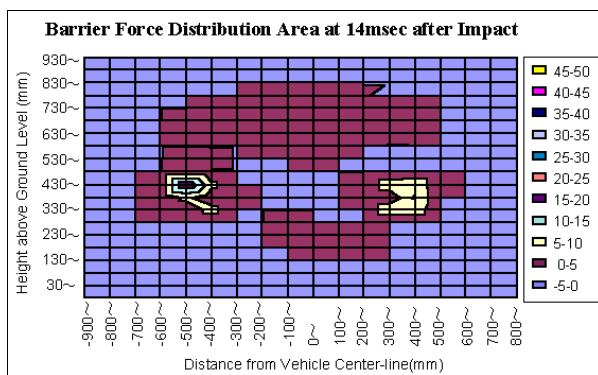


Figure 5. The condition of force distribution at 14-msec

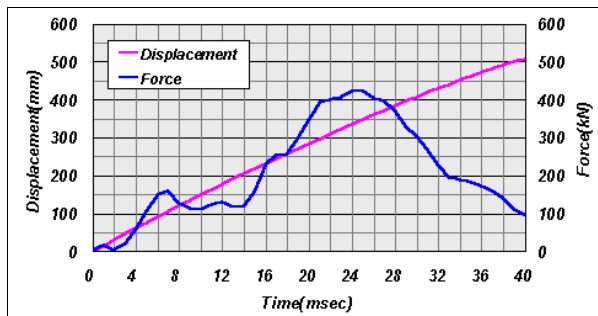


Figure 6. Force and Displacement of small hatchback

Results of FEM Analysis – 3(the case of small sedan)

Figure 7, 8 shows the distribution of barrier force at 12, 16, and 20-msec after impact.

At 12-msec (about 180 mm deformation) after impact, the force occurs around a height of 400-mm, but at 16-msec (about 240 mm deformation) and 20-msec (about 290 mm deformation) after impact, high force was observed at around a height of 200 mm.

As seen in Figure 8, in the case of this model, the force below 300 mm is observed.

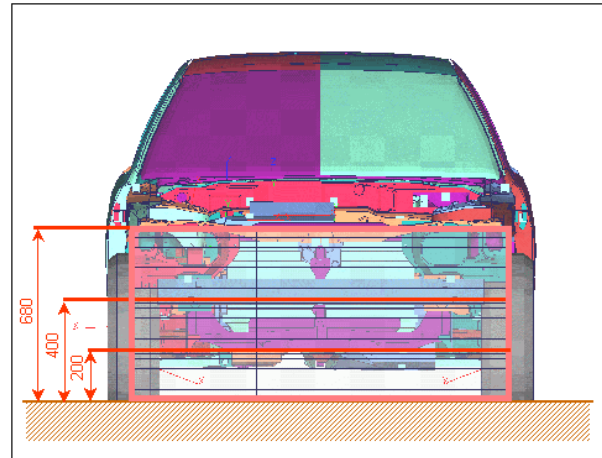


Figure 7. Front view of the small sedan

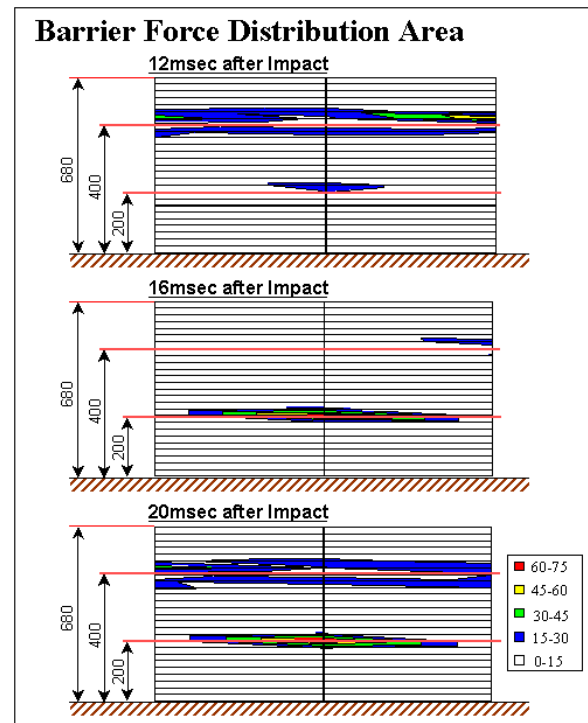


Figure 8. The condition of force distribution at 12 to 20msec

Summary of FEM Analysis Results

- I. According to these three cases of FEM analysis, it has become clear that high force occurs at a height of 130~280-mm above ground when deformation exceeds a certain amount.
- II. The force applied to the struck vehicle by the lateral member below the longitudinal member is considered not to be negligible.

III. To define the MDB barrier face height, It is not recommended to use only the height of the longitudinal member of the representative car. Adequate study of the structure of the representative car is strongly recommended.

FULL-SCALE TEST

Expectation

We compared the results of the MDB to Car Test with the Car-to-Car Test in order to evaluate the force generated by the structure below the longitudinal member.

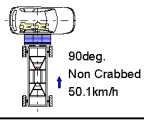
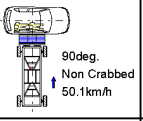
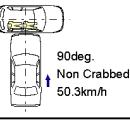
We used a vehicle approximately the average dimension of a Japanese vehicle as the striking vehicle, and the MDB height above ground was 300 mm and 350 mm. According to the results of the investigation on Japanese vehicle front-end dimension, the average height of front longitudinal member bottom is 376 mm. The height of the longitudinal member bottom of the vehicle used in this Car-to-Car Test was 370 mm, which is almost equivalent to the average height of Japanese fleet. If the height of the barrier face bottom properly represented the height of the longitudinal member bottom of the vehicle, the following result should be expected:

MDB (350 mm) to Car Test \approx (nearly equivalent) Car to Car Test, or MDB (350-mm) to Car Test < Car to Car Test (Car to Car Test is severe)

Test Conditions and Relevant Conditions

Test Conditions

As shown in Figure 9, we assessed two cases of the MDB to Car Test and one case of Car to Car Test for the identical test vehicles (struck vehicle). The detailed conditions are as follows.

	F960701 (MDB to Car)	F960703 (MDB to Car)	F960902 (Car to Car)
Impact Configuration			
Striking Vehicle			
Type	MDB	←	4dr SD*
Mass kg	950	←	1180
Ground Height mm	300 **	350 **	370 / 237 ***
Struck Vehicle			
Type	5dr HB	←	←
Mass kg	1034	←	←
Front Dummy	EUROSID-1	←	←
Seat Position	Mid Position	←	←
Rear Dummy	EUROSID-1	←	←

* : Similar to Average Characteristics of Japanese Vehicles

** : Barrier Face Bottom

*** : Longitudinal Member Bottom / Lateral Member Bottom

Figure 9. Test Conditions and Relevant Conditions

(1) MDB to Car Test

We performed the test according to the conditions of the Japanese Regulatory test procedure (same as the European Regulatory test procedure). We installed the dummy into the rear seat as well. The height of the barrier face above ground was 300 mm or 350 mm.

(2) Car to Car Test

We used a 4drSD (4-door sedan) with approximately the average front-end dimension and stiffness of a Japanese vehicle as the striking vehicle. The striking vehicle has 370 mm of front longitudinal member bottom height and 237 mm of front lateral member bottom height. The striking vehicle weight was adjusted to 1180 kg that is from 1080 kg of the average curb weight of Japanese vehicles and 100 kg with dummy and instrumentation.

Comparison of Vehicle Height

As shown in Figure 10, the top surface of the side sill height is 250mm and the H. point height is 476 mm at the front seat reference point of the struck vehicle. The barrier face bottom does not engage the sill in the MDB to Car Test. In the Car-to-Car Test, the lateral member bottom (front cross member bottom) is 237 mm and that engages the top of the Sill.

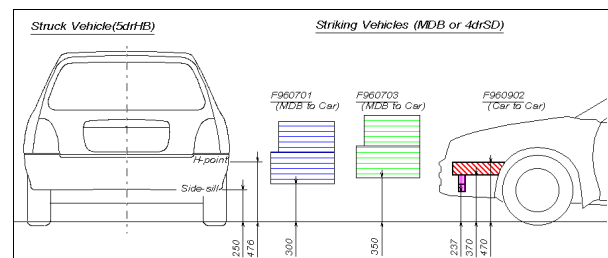


Figure 10. Comparison of Vehicle Height

Front-end dimension of Striking Vehicle at Car-to-Car Test

The length from the front surface of front bumper to the longitudinal member front-end is 110mm, as shown in Figure11. The length from the front surface of front bumper to the lateral member front-end is 160mm. at Car-to-Car Test

Comparison of Front-end Stiffness

(1) MDB to Car Test

In this test, we used the barrier face that is the multi-layer type and meets the barrier face corridor of the current European and Japanese Regulatory requirement.

(2) Car to Car Test

As shown in Figure 12, the front end stiffness of striking vehicle is close to the average stiffness of a Japanese vehicle, and is also relatively close to the barrier face stiffness.

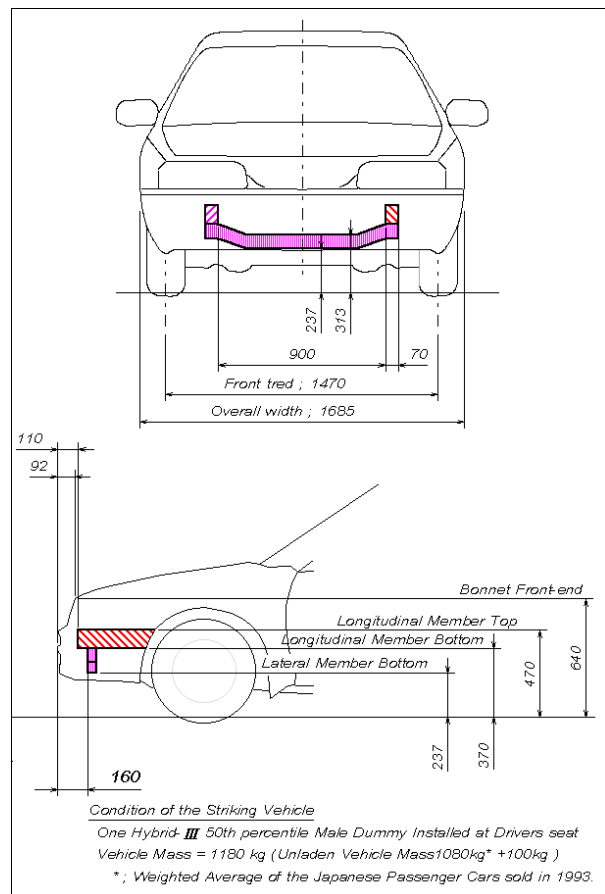


Figure 11. Front-end dimension of Striking Vehicle

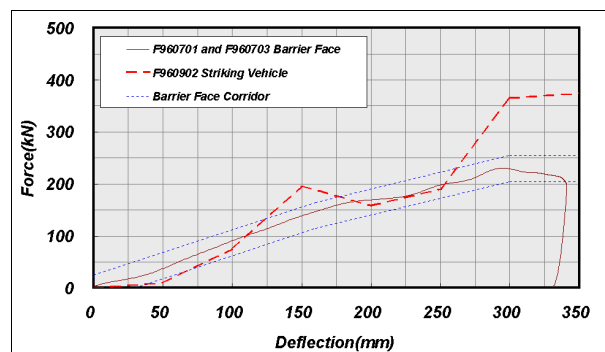


Figure 12. Front-end Stiffness

Note:

The average stiffness of Japanese vehicles means the cumulative average of vehicles made in 1993 reported in the ESV paper, in 1996 (96-S8-O-02, 96-S6-O-06) and

the weighted average of vehicles made in 1998 reported by the previous IHRA side impact WG.

However, the force distribution of the average stiffness of Japanese vehicle equivalent to each block in MDB surface is not clear since no data available.

Result of Full-scale Test

Body Deformation mode after Test

As shown in Figure 13 to 15, there is a distinct difference in the deformation between the two cases of MDB to Car test and the case of Car to Car Test. In particular, significant different deformation modes were observed at the side sill area.



Figure 13. F960701 MDB(300mm) to Car



Figure 14. F960703 MDB(350mm) to Car



Figure 15. F960902 Car to Car

Comparison of Deformation Mode of Body and Barrier Face

As shown in Figure16, the deformation modes of the struck vehicle were evaluated. At the thorax level of the body deformation, they are in the order of MDB350-mm > MDB300-mm > Car to Car, and the deformation is the lowest at Car to Car. At the pelvic level of the body deformation, they are also in the order of MDB350-mm = MDB300-mm > Car to Car, and the deformation is the lowest at Car to Car. However, at the side sill level of the body deformation, they are in the order of Car to Car > MDB350-mm = MDB300-mm, the deformation is the highest at Car to Car. The reason considered for this is that the structure (Lateral member) below the longitudinal member of striking car strikes against the side sill of the struck vehicle when the striking vehicle is the real car.

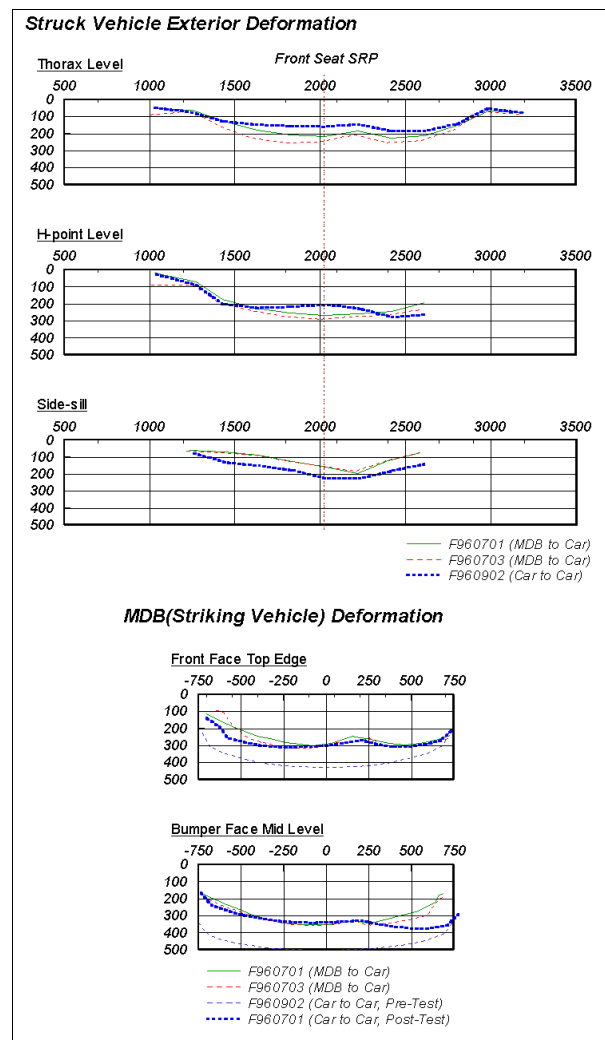


Figure 16. Vehicle Exterior Deformation

Then, as shown in Figure16, the deformation mode of the striking vehicle and MDB is as follows:

At the barrier face top (or bonnet top) level, the striking vehicle and the MDB at Car-to-Car Test show the relatively close deformation mode. At the bumper central level, the striking vehicle at Car-to-Car Test shows that the deformation mode is relatively close to the MDB except the left end that strikes around the back door of the test vehicle.

Injury Value of Front Seat Dummy

As shown in Figure17 to 20, The HPC values, Head Performance Criteria, are almost equivalent in all three conditions.

The RDC, Rib Deflection Criteria, values (maximum value of three ribs) are in order of MDB300-mm = MBD350-mm > Car-to-Car. Similarly, V*C values (maximum value of three ribs) are in order of MDB300-mm (Mid) = MBD350-mm (Upper) > Car-to-Car.

The APF, Abdominal Peak Force, value are in order of MDB300-mm = MBD350-mm > Car-to-Car.

The PSPF, Pubic Symphysis Peak Force, values are in order of MDB300-mm > MBD350-mm > Car-to-Car for the PSPF as pelvic injury value.

Therefore the injury values in the condition of Car-to-Car are the lowest throughout all results.

Injury Value of Rear Seat Dummy

As shown in Figure21 to 24, The HPC values are in order of MDB300-mm > Car to Car > MDB350-mm.

The RDC values (maximum value of three ribs) are in order of MBD350-mm (Lower) > MDB300-mm (Lower) > Car to Car (Upper), the value at MBD350-mm is the highest. For the V*C (maximum value of three ribs) values are very similar and low in all three conditions.

The APF values are in order of < MBD350-mm > MDB300-mm > Car to Car.

The PSPF values are in order of MBD350-mm > MDB300-mm > Car to Car.

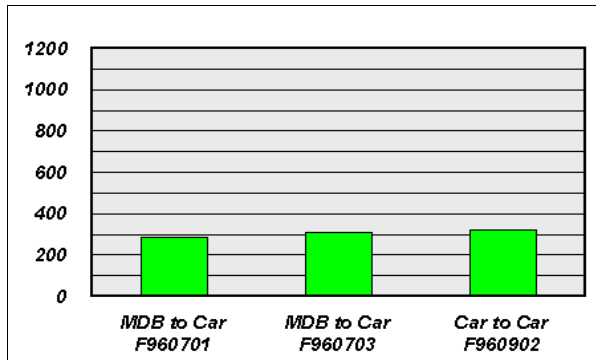


Figure 17. HPC of Front Seat

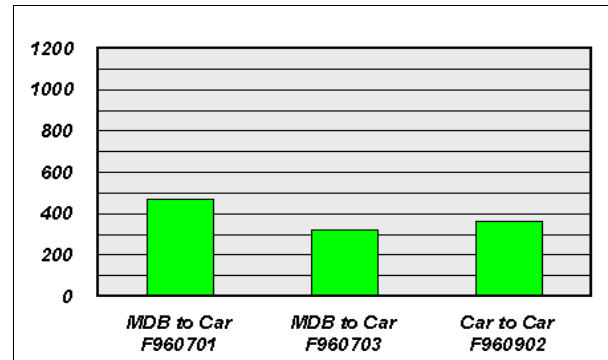


Figure 21. HPC of Rear Seat

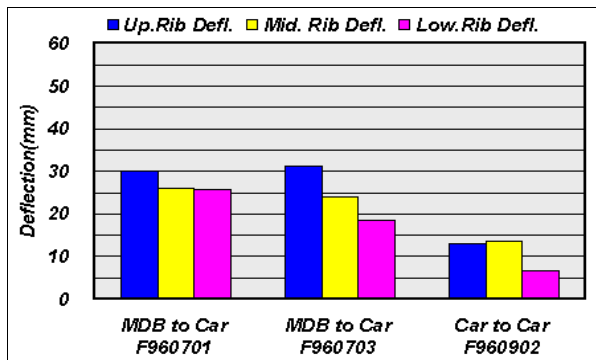


Figure 18. RDC of Front Seat

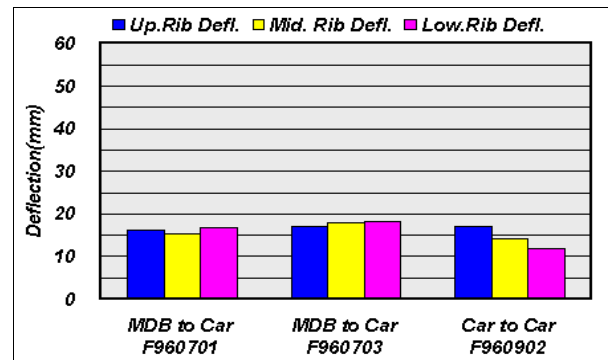


Figure 22. RDC of Rear Seat

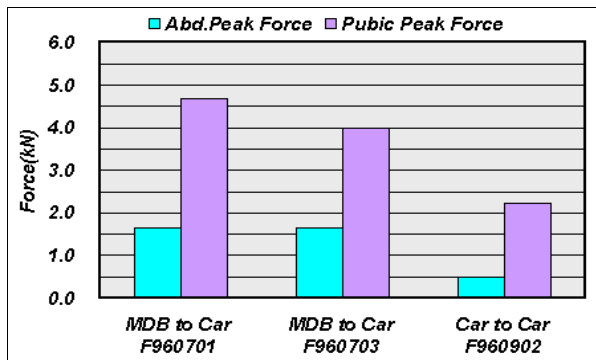


Figure 19. APF and PSPF of Front Seat

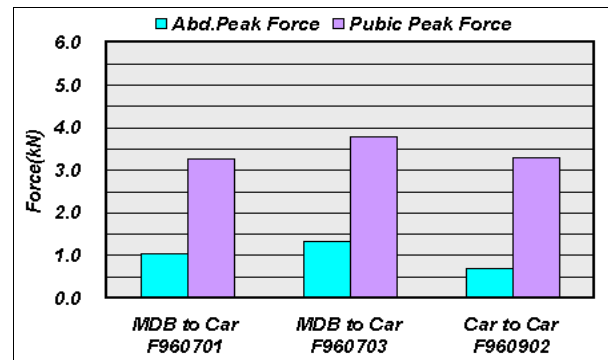


Figure 23. APF and PSF of Rear Seat

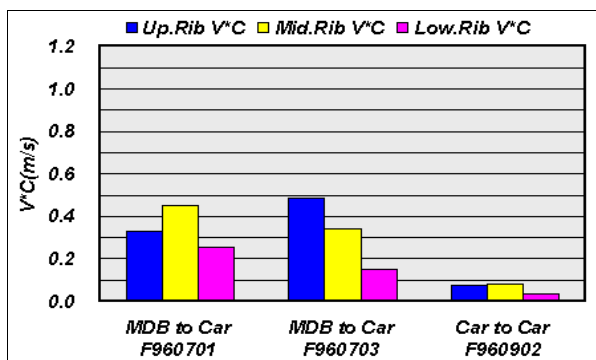


Figure 20. VC of Front Seat

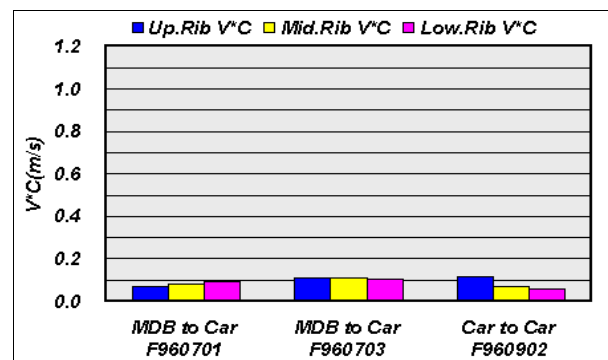


Figure 24. VC of Rear Seat

Velocity Change of Each Part of Body, and Dummy

As shown in Figure 25 to 27, the velocities of door and dummy rib tend to rise earlier at MDB350-mm than at MDB300-mm. The velocities of each part of the door and dummy tend to rise slowly and moderately. The velocity change of the body is the largest at Car to Car than with MDB tests due to the engagement of the sill and front structure of impacting car.

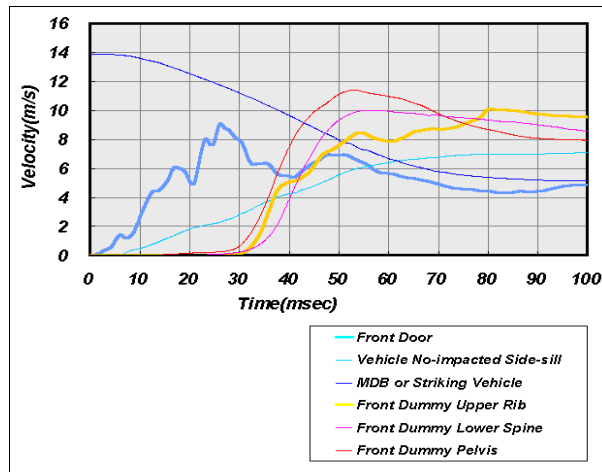


Figure 25. Velocity of F960701 MDB(300mm) to Car

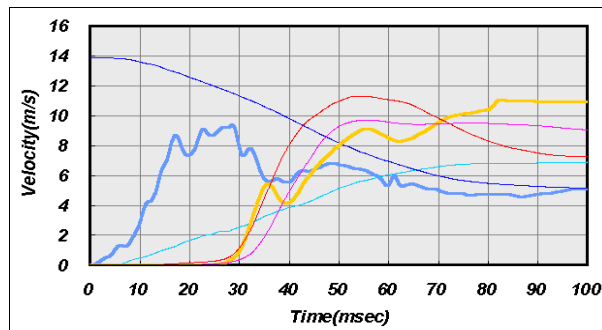


Figure 26. Velocity of F960703 MDB(350mm) to Car

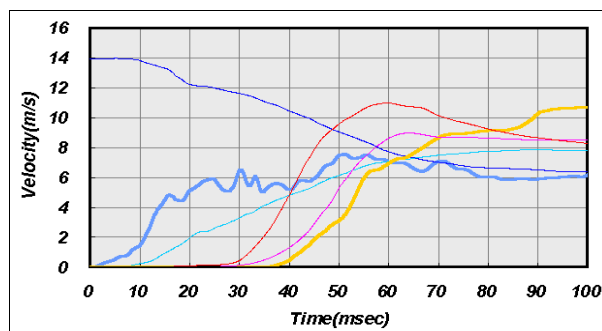


Figure 27. Velocity of F960902 Car to Car

Summary of Full-scale Test Results

To compare the MDB (350-mm) to Car Test with Car-to-Car Test, at Car-to-Car Test, the deformation of the side sill is larger and the deformation of body around the dummy impact area is smaller. This is because the structure (front cross member) below the longitudinal member bottom height (front side member bottom height) engages the side sill of struck vehicle.

As a result, intrusion of the front dummy impact area became smaller and resulted in lower injury numbers in all dummy regions.

This result suggests that the MBD height selected from bottom height of longitudinal member does not well simulate actual vehicle crash condition.

CONDUCT OF ADDITIONAL INVESTIGATION ON VEHICLE FRONT-END DIMENSION

As shown in Table 1 and Figure 28, the member companies of JAMA have conducted an additional investigation on the following two items in addition to the dimensions already investigated.

- a; Lateral Member Bottom Height
- b; Lateral Member Front-end from Vehicle Front-end

The results of a and b are 256 mm and 138 mm respectively. It has become clear that the front cross member bottom height is about 120 mm lower than the longitudinal member bottom height of the Japanese vehicles investigated.

	Measurement Point	(mm)
1	Overall Width	1852
2	Tread	1428
3	Front Shock Absorber Fixing Width	1007
4	Longitudinal Member Width(Outer Surface)	982
5	Longitudinal Member Width(Inner Surface)	853
6	Front Shock Absorber Fixing Height	788
7	Engine Top Height	735
8	Bonnet Front-end Height	736
9	Longitudinal Member Top Height	504
10	Longitudinal Member Bottom Height	376
11	Engine Bottom Height	267
12	Front Shock Absorber Fixing from Vehicle Front-end	804
13	Bonnet Front-end from Vehicle Front-end	99
14	Longitudinal Member Front-end from Vehicle Front-end	138
a	Lateral Member Bottom Height	256
b	Lateral Member Front-end from Vehicle Front-end	138

Table 1. Vehicle Geometry Additional Investigation

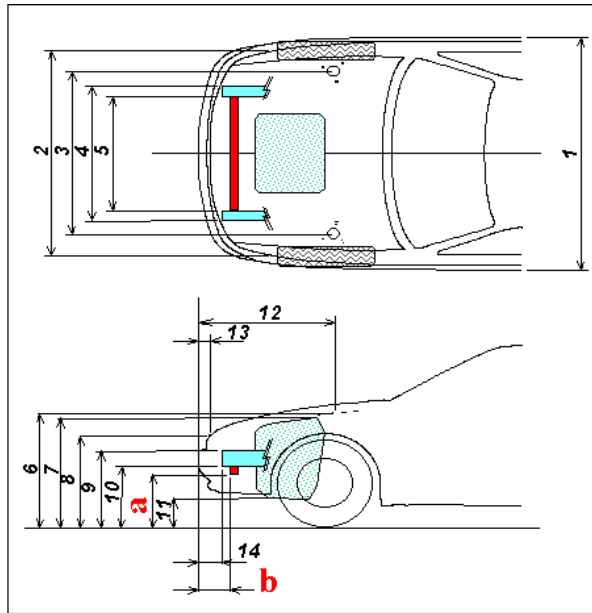


Figure 28. Vehicle Geometry Additional Investigation

CONCLUSIONS

As the above description, from the FEM analysis results of frontal impact and the comparison of the results of the MDB to Car Test and Car-to-Car Test show, the following facts have become clear:

- (1) The force that is applied to the target by the structure (front cross member) below the longitudinal member should be considered.
- (2) The actual car impact condition is not properly represented when the height of the MDB barrier face above ground is determined based on the bottom height of longitudinal member. The height of the lateral member bottom (front cross member bottom) must be taken into account.

RECOMMENDATIONS

The following items should be addressed in order to discuss the geometry of the MDB barrier face.

- (1) The type of vehicle selected to be simulated as the MDB may differ in each market.
- (2) In order to suggest the dimension of the MDB face, it is necessary to investigate and review the front-end structure of the vehicle.

SUGGESTION OF BARRIER FACE GEOMETRY

Taking into account the results of the additional investigation on dimension, we have discussed the recommended geometry of the barrier face as shown in Figure 29. As a result, it is similar to the US barrier in geometry standpoint (Figure 30).

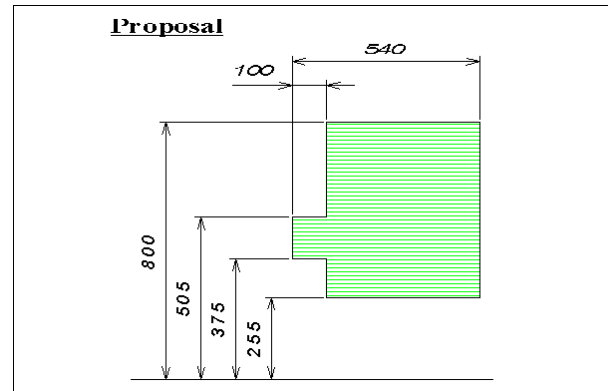


Figure 29. Proposal of Barrier Face Geometry

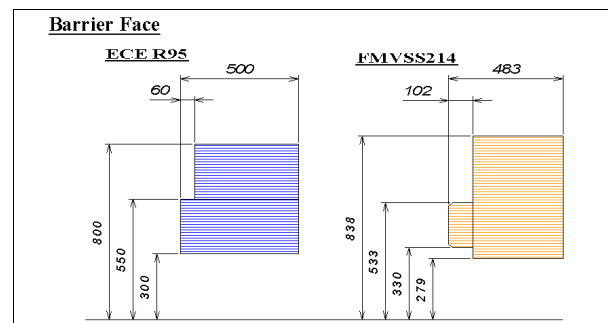


Figure 30. Reference of Usual Barrier Face Geometry

FUTURE PLAN

Further study to define the reasonable MDB specifications will be under taken by the JAMA Side Impact Working Group activities in conjunction with IHRA activities.

REFERENCES

IIHS(INSURANCE INSTITUTE FOR HIGHWAY SAFETY) STATUS REPORT.
Vol. 34, No. 9, October 30, 1999